DOCKET NO. 50-250
-251

Eor Div of Compliance

REPORT ON

CRITERIA

FOR

CADWELD SPLICES

FLORIDA POWER AND LIGHT COMPANY
TURKEY POINT, UNITS NO. 3 & 4
BECHTEL JOB NO. 5610

MAY 1968

Bechtel Associates
Gaithersburg, Maryland

TABLE OF CONTENTS

INTRODUCTION

The Atomic Energy Commission, Division of Compliance, Region II Group, on their January 23 & 24, 1968, visit to the Turkey Point site expressed concern regarding the interpretation of the visual quality control acceptance standard Paragraph 6.3 of Appendix A, Supplement No. 8 to the PSAR. It, therefore, became evident that this standard could use clarification to provide sufficient guidance to establish the effect of void size upon the strength capability of the splice.

As a result, Bechtel, Cadweld and Florida Power and Light have investigated the effect of voids on the strength of Cadweld splices. This investigation consisted of:

A. Review of a program in which Cadweld tested 14S bars with artificially induced voids of varying sizes. This was followed by a calculation of the loss of shear stress transfer surface which would be tolerated and extrapolation of such allowable loss to 18S bars.

B. A program by Cadweld to test 18S bars with artificially induced voids, eccentricities and misalignments.

C. A program by Bechtel to test splices questioned by the Atomic Energy Commission after measuring void areas.

Upon commencement of the above investigation on January 31, 1968, the Bechtel Cadweld Inspection Program was modified to measure and record any occurrence of end voids in the splices. Subsequent test results have been correlated with measured voids and presented in this report.

SUMMARY AND CONCLUSIONS

SUMMARY

The Cadweld quality control and production test splices at Turkey Point up to January 23, 1968, averaged 94,800 psi. for the horizontal splices and 98,000 psi. for the vertical splices, both of which are in excess of specification requirements. The laboratory and field testing and review programs verify that it is not necessary to have filler material for 360 degrees at the end of the horizontal Cadweld splice sleeve to obtain the specification strength requirements.

Test results indicate that there is no direct linear relationship between void size and the strength of the Cadweld splice. The presence of a large void does, however, reduce the strength carrying capacity of the splice. It is, therefore, believed that the void size must be limited in order to achieve a confidence level in the splices.

These tests have validated the selection of acceptance criteria applied to Cadweld splices. They also indicate that a combination of maximum eccentricity, when the bar is in contact with the sleeve for its entire length, and voids have some accumulative effect in reducing the load carrying capacity of the Cadweld splice. To preclude the necessity of a separate void criteria to cover the case of voids combined with maximum eccentricity, a clearance criteria has also been established and will be applied to all splices.

CONCLUSIONS

A. Test results indicate that existing specifications for visual inspection need to be supplemented to insure that excessive loss of contact area due to voids does not cause deterioration of average and minimum splice strengths below specified limits. The Specification for Cadweld splices is attached hereto as Appendix C. The strength requirements have been updated over those set forth in Appendix A of Supplement 8 of the PSAR and conform to those of more recently licensed plants using similar containmer structures.

B. Tests of splices with voids of less than one (1) square inch at either or both ends of the splice sleeve indicate strengths well above the minimum ultimate capacity of the bar.

CONCLUSIONS (continued)

C. No voids yet measured have resulted in failure to meet 125% of minimum yield strength of the reinforcing bar tests, except in one case of combined void and maximum eccentricity.

D. By limiting voids to three (3) square inches and eccentricity so that the minimum sleeve clearance is 1/16 of an inch, assurance is obtained that the average ultimate strength of the splices will not deteriorate below the specified minimum of the reinforcing bar.

E. Preheating of bar and sleeve prior to firing as called for in Cadweld Specification for Splicing Reinforcing Bar Using the Cadweld Process has been given additional emphasis and attention by the Cadweld Inspector.

F. A full-time Cadweld splicing inspector has been assigned to approve cleaning, fit-up, alignment, splicing procedure and materials; visually inspect each completed splice; measure any void area and monitor all operations related to the above.

G. Procedures followed in preparing Cadweld splices at Turkey Point are essentially the same as those employed at similar plants now under construction.

CADWELDING AT TURKEY POINT NUCLEAR POWER STATION:

The Cadweld Splice

Since June 1967 the Cadweld process, a mechanical method for joining reinforcing bars, has been used for the splicing of 14S and 18S rebar in the reactor containment and turbine buildings. A description and discussion of the mechanics of the rebar splice are detailed in Appendix A of this report.

Cadweld Splicing Material Control

The "T" Series, Cadweld II materials and equipment have been used for the horizontal and vertical splicing of A-432 rebar. A minimum inventory of Cadweld materials is maintained by Field engineering. Upon receipt of the materials by jobsite Purchasing personnel, they are immediately stored in the special, heated Cadweld trailer. Certified Mill Tests on each lot of Cadweld materials are received by the Quality Assurance Engineer and filed according to shipment date. Materials are issued to the Ironworker Cadweldors only as required for a days work, and excess materials are returned the same day to the Cadweld Storage Trailer.

Operator Training and Qualification

Prior to initial operator qualification tests, the Cadweld factory representative and Bechtel welding inspectors conducted a program to train Ironworkers who had been specially selected as Cadweld operators. This pre-training was oriented around rebar preparation and alignment, care and cleaning of materials and equipment, reporting of malfunctions and unserviceable equipment and Cadweld testing.

The Cadweld representative, together with Bechtel supervisory and Quality Assurance personnel, demonstrated the causes for bad splices by actually causing sample malfunctions.

Each individual on each team of Cadweldors was then qualified for the position, size and grade of bar required. The qualification records are maintained in the QAE files and also in the 5610 jobsite welding files. Both Florida Power and Light and Bechtel perform spot checks approximately once a week of the qualification records of active Cadweldors.

Inspection (Prior to January 23, 1968)

Splice Preparation

After checking the pre-alignment of the rebars to be spliced, the bar ends are cleaned by power brush, and gapped 3/16" to 1/4". The Cadweld sleeve is inspected for proper grooving and lack of moisture by the operator after it is unwrapped from the rust inhibiting paper. After the operator checks the cleaniness and dryness of the bar, he performs an additional visual check of the proper centering of the 1/4" gap through the riser port prior to seating of the pouring basin.

During firing of the Cadweld, the operator checks the molten metal flow and the color of the smoke. The operator takes special note of the condition of the riser after the equipment has been removed from the splice, and gives the riser a number of sharp blows to insure that it is good metal rather than slag. The operator is responsible for removing the asbestos packing from the ends of the splice sleeve and for checking the amount of filler metal visible at both ends. Any unusual conditions during any of these operations are brought to the immediate attention of the inspector and/or foreman as warranted.

Finished Splice

Cadweld visual inspection is performed by the Bechtel welding inspector within twenty-four (24) hours of the completion of the Cadweld splice. The inspection required by Bechtel Specification No. 5610-C-30, Section 6, is performed on each and every splice; the Inspector's Identification Mark is placed on each splice after the inspection. A silver mark indicates Approval, a red mark indicates Rejection, a yellow mark indicates "Hold", and a green mark is placed on top of the previously rejected splice, if subsequent approval takes place. All visually rejected Cadweld splices are placed in a reject pile near the jobsite Cadweld trailer.

Visual rejects are discussed and analyzed with the foreman and crews, in addition to the Quality Assurance Engineer and the responsible Field engineer and Superintendent.

Inspection (Since January 23, 1968)

Since January 23, 1968, a full-time inspector has been assigned to monitor this portion of the Quality Assurance Program including those activities described above. His functions include the following:

1. To verify that cleaning, preheating, fit-up and casting are in accordance with the requirements of the Cadweld Specification.

2. After completion of the splice and removal of packing material to visually inspect the completed joint in accordance with Specifications.

3. Measure and record the presence and depth of any void at each end of the Cadweld sleeve. The area of any void is assumed to be the circumferential length as measured at the inside face of the sleeve times the maximum depth of the wire probe minus 3/16".

4. Continue to submit a record of each splice inspection to the QAE for permanent retention in project files. Each splice is numbered and identified on a drawing which indicates its location in the structure. The records have been extended to include a description of contained end voids and sizes.

Testing

Sister Splices

The Quality Assurance Engineer, in conjunction with the Bechtel welding inspector, decides which sister splices will be made for testing in accordance with Paragraph 5.0 of Specification 5610-C-30. Emphasis is placed upon random selection of splices.

After full section tensile tests are performed on the Cadwelded #18S rebar at Pittsburgh Testing Laboratory, Pittsburgh, Pa., all failed splices and selected representatives splices are returned to the jobsite for additional analysis, including splice sectioning. These splices are then stored on the jobsite.

Random Cut Outs

At the insistence of the Atomic Energy Commission, Division of Compliance, Bechtel agreed in October of 1967, to remove two (2) random production splices for each 100 "sister" splices tested. It was made perfectly clear to both the Client and the Atomic Energy Commission, that this was in no way a reflection of the adequacy or the representativeness of the "sister" test splice program. As of January 23, 1968, three (3) random cut outs were made and have yielded the following results: 82, 400 psi., 101, 500 psi. and 76, 400 psi. All of these meet the acceptance criteria of the Cadweld Specification.

Horizontal Cadweld Tensile Strength Data Through January 23, 1968.

Note: Total Nuclear-related, in-place Production Cadwelds through January 23, 1968 - 1, 989. Test results based on Pittsburgh Testing Laboratory (Pittsburgh) Reports through January 17, 1968.

a.	Total Number of Horizontal Test Splices	-	47
	Average Tensile Strength (all tests)	-	94, 823 psi
	Median Tensile Strength (all tests)	-	97, 500 psi
b.	Number of Horizontal Pull-Out Failures	-	38
	Highest Tensile Strength	-	105, 500 psi +
	Average Tensile Strength	-	93, 508 psi
	Median Tensile Strength	-	96, 000 psi
	Lowest Tensile Strength	-	66, 750 psi +

Testing (continued)

c. Number of Horizontal Rebar Failures - 9

Highest Tensile Strength	-	109,100 psi
Average Tensile Strength	-	100,378 psi
Median Tensile Strength	-	102,300 psi
Lowest Tensile Strength	-	82,400 psi

The results of the above tests indicate that the Cadweld splices met the strength requirements as presented in Specification 5610-C-30 included as Appendix C.

Vertical Cadweld Tensile Strength Through April 6, 1968.

a. Total Number of Vertical Test Splices - 26

Highest Tensile Strength (all tests)	-	107,750 psi
Average Tensile Strength (all tests)	-	100,700 psi
Median Tensile Strength (all tests)	-	101,100 psi
Lowest Tensile Strength (all tests)	-	85,500 psi

b. Number of Vertical Pull-Out Failures - 20

Highest Tensile Strength	-	107,750 psi
Average Tensile Strength	-	101,100 psi
Median Tensile Strength	-	100,500 psi
Lowest Tensile Strength	-	85,500 psi

c. Number of Vertical Rebar Failures - 6

Highest Tensile Strength	-	106,400 psi
Average Tensile Strength	-	102,700 psi
Median Tensile Strength	-	101,500 psi
Lowest Tensile Strength	-	98,850 psi

Site Production Testing Results Since January 23, 1968.

Listed below are the results of all A-432 18S Cadweld splice tests, except for those shown in Table 2, destructively tested since January 23, 1968. These include all sister splices, production cut outs, crew qualification splices and visually rejected production splices.

Splice Number	Type	Void Area Sq. In. No. End	Void Area Sq. In. Other End	Tensile Strength P.S.I.	Remarks
386	Hor.	0.24	0.37	101,500	Pull Out
387	Hor.	0.21	None	97,000	Pull Out
QV-G	Vert.	0.41*	1.3	96,400	Pull Out (qual. splice)
390	Hor.	4.43*	1.68	78,400	(1) Pull Out (Reject for Void)
217	Hor.	0.35*	0.26	94,500	Pull Out
224	Hor.	0.40	0.25*	98,600	Pull Out
258	Hor.	None	5.11	100,600	(1) Fracture in Bar (Reject Exc. Void)
127	Hor.	None	None	104,750	(2) Fracture in Bar (Reject for Eccentricity)
112	Hor.	0.89	0.88	100,750	Fracture in Bar
121	Hor.	0.44	None	101,500	Fracture in Bar
86	Hor.	None*	None	96,000	Pull Out

* Indicates the Failed End of the Cadweld Splice.

(1) Indicates production splices which were rejected visually in accordance with the three (3) square inch void criteria.

(2) This splice was visually rejected for an eccentric condition.

All other tests noted in this table were sister splices.

Combined Tensile Strength

The combined average of all production test splices up to April 6, 1968, is 98,100 psi.

Evaluation and Feed-Back to Supervision & Operators

Returned splices showing evidence of improper operator or material performance are specifically reviewed with the crew that performed the splice and with appropriate levels of supervisor. For example, sister splice No. 41-315H, pulled out at 66,750 psi was reviewed with both shifts of Cadweldors and their supervisors before further Cadwelding was permitted. The adjacent production splice was immediately cut out and subsequently tested. This splice yielded a tensile strength pull out failure of 105,500 psi. These test results have been included under Item b above, Horizontal Cadweld Tensile Strength Data Through January 23, 1968, and have been indicated thus (+).

CADWELD SPLICE STUDIES

Cadweld had previously performed a series of induced void tests using 14S bars and based upon these tests had extrapolated a void criteria of three (3) square inches for 18S splices. The test results, extrapolation and relationship to stress areas are presented in Appendix B.

To support the three (3) square inch void criteria the Cadweld manufacturer made and tested a series of 18S test splices with various sizes of induced voids. Some with maximum eccentricity were also made and tested. Voids sizes were recorded and the bars tensile tested in the same manner as a production bar. The maximum size induced void used for the 18S test splices was 4.08 square inches and it achieved a stress value of 88,875 psi before the bar pulled out of the sleeve. The results of these tests are shown in Table 1 below.

Six (6) splices exhibiting the largest voids and eccentricity were also selected for destructive testing from the group questioned by Atomic Energy Commission, Compliance Personnel. The void sizes and condition of the splices were documented prior to testing. The test results are tabulated in Table 2 and indicate that eccentricity in the presence of voids accumulatively reduces the tensile carrying capacity of the splice. It is noted, however, that although splice No. 47 had a void area of 3.22 square inches and maximum eccentricity, it achieved a value of 73,750 psi which is within 2% of 125% minimum tensile yield strength (75,000 psi) of the reinforcing bar.

TABLE 1

TEST RESULTS OF 18S CADWELD INDUCED VOID TEST SAMPLES

Sample No.	Vert. or Horiz.	Void Sizes (Depth & Width)	Effective * Void Area (in^2)	Failure Stress (psi)	Failure Mode
T-1153	H	1.40 x 3-5/16	3.85	91,750	BPO
T-1154	H	1.55 x 3	4.08	88,875	BPO
T-1155	H	3.33 x 1	3.14	93,000	BPO
T-1156	H	3.05 x 1	2.86	89,750	BPO
T-1157	H	Max. Eccentric	None	96,000	BB
T-1158	H	Max. Eccentric	None	96,250	BB
T-1159	V	3/4" Total Circle	3.98	91,500	BPO
T-1160	V	3/4" Total Circle	3.98	85,250	BPO
T-1161	V	Max. Angle	None	95,600	BPO

BPO = Bar Pulled Out BB = Bar Broke

* Effective Void Areas = Circumferential Length x (Depth - 3/16")

The test strength of each of the above samples exceeds 125% minimum tensile yield stress of 75,000 psi by a wi e margin. Average tensile stress of all 9 samples is 91,997 psi, which is above the minimum ultimate strength for this bar material.

Samples T-1157 and T-1158, were made with the rebar touching the sleeve, that is, the bar at maximum eccentricity with respect to the splice sleeve. The point of contact was at the bottom of the bar, the sleeve being raised to its maximum position by the thumb screws in the sleeve. Both samples broke in the bar outside of the splice sleeve.

Sample T-1161 was made with bars at the maximum angular misalignment which could be physically made within the sleeve. Internal portions of the bars and the bars at the outer edges of the splice sleeve were in contact with diametrically opposite sides of the sleeve. This sample failed by pulling out of the sleeve but at a value beyond the minimum ultimate strength of the reinforcing bar.

TABLE 2

Test results of the Turkey Point 18S production splices taken from those questioned by the Atomic Energy Commission, Compliance Personnel, are tabulated below. These contained the most severe condition of voids and eccentricity found in the subject group of 59 production splices.

Sample No.	Deficiencies Selected	Effective Void Area Numbered End	Effective Void Area Other End	Tensile Strength	Type Failure
29	Void	2.37	0.88*	95,650	PO
46	Void	1.44*	3.22	87,900	PO
41	Void	0.25	7.88*	78,750	PO
47	Void & Eccentric**	1.55	3.22*	73,750	PO
26	Eccentric	2.03	0.64*	87,400	PO
48	Eccentric	1.40	0.94*	85,000	PO

* Indicates the failed end of the Cadweld.
** Reinforcing bar was touching the sleeve.

PO = Pull Out

Test results presented in Tables 1 and 2 show splices with void sizes of 3, 4, 5 and 7 square inches which yielded strength in excess of 125% (75,000 psi) yield strength of reinforcing bar. No voids yet measured have resulted in failure to meet 125% of minimum yield strength of the bars tested, except in one case of combined void and maximum eccentricity where the bar was touching the Cadweld splice sleeve.

DISCUSSION OF RESULTS

Review of destructive test results of induced void splices, sister splices and production splices indicate that the mechanism of a Cadweld splice is not very sensitive to void size and eccentricity, and that there is no direct linear relationship between void size and tensile strength.

The allowable void areas for the criteria have been selected with the intent of providing splices which will have a minimum average tensile strength equal to or greater than the minimum ultimate strength (90,000 psi.) of the reinforcing bar and each to have a minimum of 125% of bar tensile yield strength (75,000 psi.). The maximum allowable stress used as a design criteria for the 18S A-432 reinforcing steel in the containment mat was 60,000 psi. All these items, therefore, provide additional assurance and safety factor in the overall integrity of the structure.

The combination of a void and maximum eccentricity in the splice can have an additive effect on reducing the tensile load carrying capacity of the splice. It is, therefore, recommended that the condition of acceptable eccentricity or concentricity be limited to a minimum gap of 1/16 of an inch between the reinforcing bar (deformations) and the Cadweld sleeve. The main purpose of this gap is to provide an annulus through which the filler material can flow. This gap may be obtained by normal fit-up and alignment practices or by the insertion of a wire (hairpin) between the reinforcing bar and sleeve. This wire may be left in and in many cases specifically inserted to provide an escape route for the gases generated during the casting of the filler material.

As of April 24 approximately 382 horizontal Cadweld splices have been made in conjunction with the mat for Unit 4. Thirty-six (36) splices contained voids of one (1) to two (2) square inches and nine (9) had voids of two (2) to three (3) square inches.

APPENDIX A

CADWELD REINFORCING BAR SPLICES

The CADWELD splice for rebar is not a weld, but a mechanical coupler. The name CADWELD is a copyrighted trademark which ERICO owns. The CADWELD name was derived from the developer's name, Dr. Charles A. Cadwell. Hence, the products of the company were called CADWELD and the product name.

The CADWELD mechanical rebar splice develops its tensile capacity by mechanically interlocking the deformations on the rebar with deformations (annular grooves) inside the splice sleeve. The mechanical interlocking is through filler metal which is exothermically created. The splice will not work on smooth, undeformed bar.

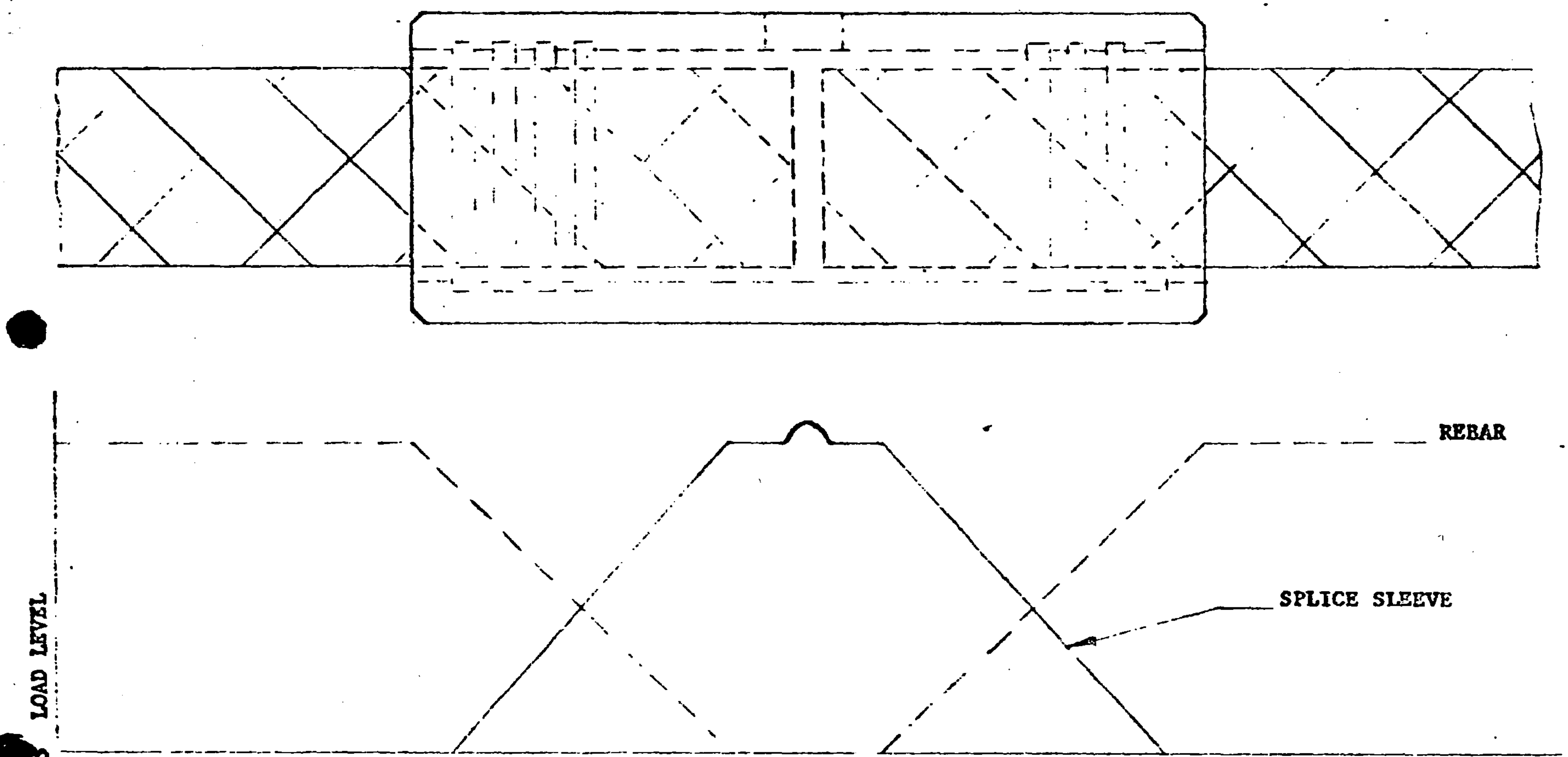
The splice sleeve is designed to have a cross-sectional area of sufficient size to carry the required tensile loading for a specific rebar grade. The splice sleeve is long enough to cover and engage sufficient deformations on the rebar to surface develop (by shear action) the required tensile strength.

The attached drawing indicates the means of transfer of tensile loads from the rebar to the splice sleeve and back to the rebar at a splice.

Compression loading is transferred by filler metal (in compression) between the bar ends. The CADWELD splice uses a spacer to assure gapping of the bar ends and permit filler metal to flow between the bar ends. The splice sleeve acts as a circumferential reinforcing hoop when the system is under compressive loading.

The CADWELD splice is well suited for field use as it does not require the skill of a certified arc welder.

The fact that the CADWELD splice is independent of bar chemistry is probably its most outstanding feature. This is quite important as ASTM Specifications on bar steel chemistry limit only the phosphorus content. Thus, carbon, manganese and other elements which control weldability are not limited by specification.



DET.	PART NUMBER	NO. REQ.	DESCRIPTION

BILL OF MATERIAL

Tensile Load Distribution on Rebar
and CADWELD Splice Sleeve

CADWELD
ERICO PRODUCTS, INC. CLEVELAND, OHIO

Drawn GT Chkd. LG	Date 10 Jun 66 Scale	XE-315

APPENDIX B

CADWELD 14S INDUCED VOID TEST RESULTS

AND

EXTRAPOLATION DATA

The strength of the 14S and 18S splice are mathematically related considering the following ratios for each of the bar sizes.

1. $\frac{\text{Sleeve Groove Area}}{\text{Bar Surface Area}}$

2. $\frac{\text{Minimum Deformation Shear Area}}{\text{Bar Surface Area}}$

A correction factor, which is the minimum ratio of the above corresponding values between the bar sizes is then applied. To establish the allowable void area in a given bar size the following relationship is used:

Allowable Void Area = 0.15 x Effective Bar Area x Correction Factor

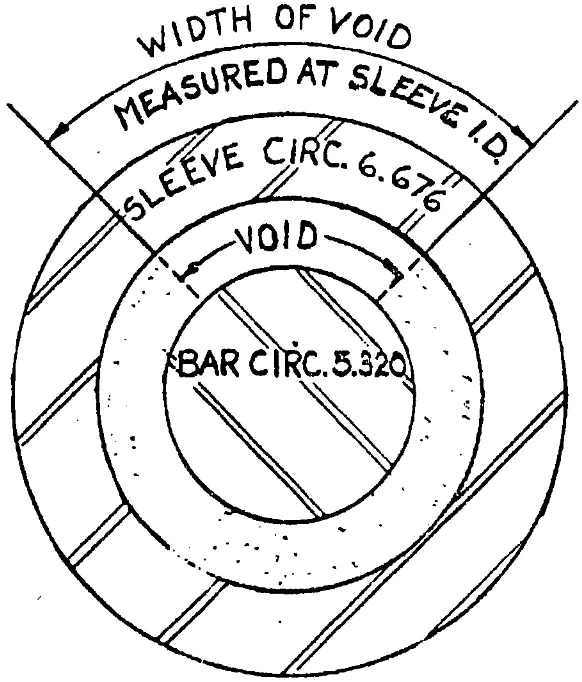
Where 0.15 x Effective Bar Area is that void fraction verified by the tests on 14S Bar material.

VOID ANALYSIS ON T-14101 & T-14101-H TEST SAMPLES

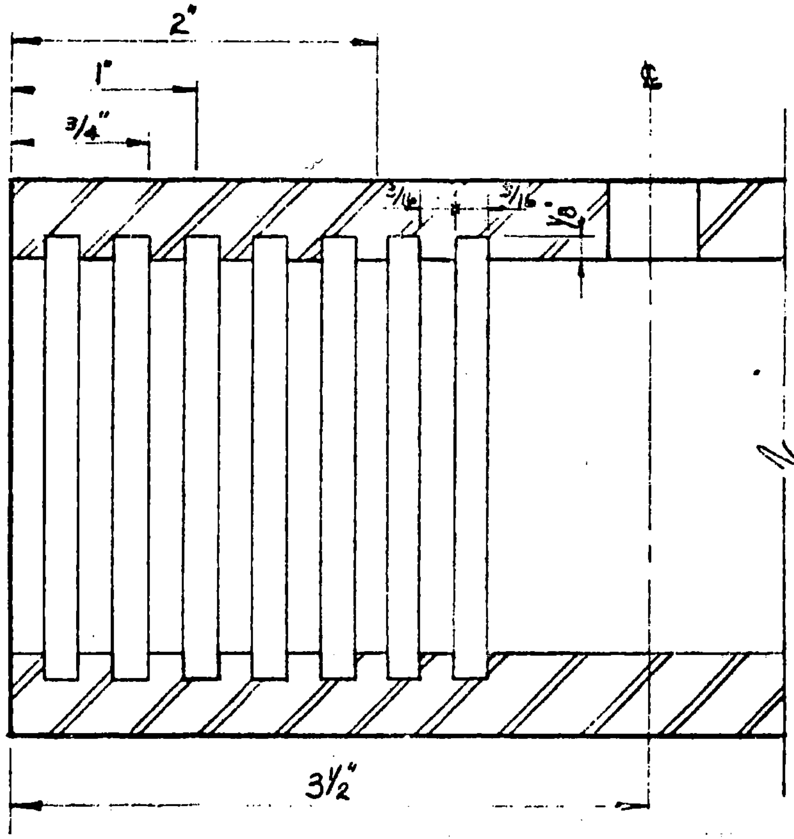
ample No.	Posit. Horiz. V	Effective Void (beyond 3/16") Area at slv. in^2	& Area at slv	Area at bar in^2 +	& Area at bar	Groove Area Lost in^2	%	Failure Load psi	Type *
-10 79	H	5/8 X 1-3/16 .508	2.297	.405	2.436	.234	2.670	93,778	BB
-1080	H	5/8 X 1-1/16 .664	3.002	.529	3.181	.352	4.017	92,556	BB
T-1081	H	1 X 1-3/16 1.188	5.372	.974	5.696	.563	6.425	92,222	BB
T-1082	H	1 X 1-3/16 1.188	5.372	.974	5.696	.563	6.425	93,333	BB
T-1083	H	1-3/4 X 2-1/16 3.609	16.319	2.876	17.299	1.969	22.472	93,222	BB
T-1084	H	1-5/8 X 2-3/16 3.555	16.075	2.833	17.040	1.828	20.862	93,778	BB
T-1085	H	3 X 1-13/16 5.438	24.590	4.334	26.069	2.813	32.104	111,333	PO
T-1086	V	1 X 1-5/16 1.3125	5.935	1.046	6.291	.750	8.559	106,222	SB
T-1087	V	1 X 1-13/16 1.8125	8.196	1.445	8.691	.938	10.705	107,111	SB
T-1107	V	9/16" circ. 3.755	16.980	2.993	18.003	2.502	28.56	97,778	PO
T-1108	V	1-1/16" circ. 7.093	32.074	5.653	34.003	3.754	42.84	77,111	PO

\+ Based on ratio of diameters, void on bar assumed to be $\frac{(1.693)}{(2.125)}$ = .797 void at sleeve inner surface.

* BB = Bar broke away from splice.
SB = Splice sleeve broke at center.
PO = Bar pulled out of splice sleeve.



$\left(\frac{5.320}{6.676}\right)$ VOID AT BAR SURFACE = .797 VOID AT SLEEVE I.D.



BECHTEL CORPORATION POWER AND INDUSTRIAL DIVISION	FLORIDA POWER & LIGHT COMPANY TURKEY POINT NUCLEAR UNITS 3 & 4	JOB No. 5610	
		SK-C-	REV.

REV. | DESCRIPTION | ENG | DP | CHK

Data Summary -- Maximum voids, but exceeding 90,000 psi.

Horizontal Test Splice - T-15101-H

Bar 55.5 ksi yield, 92-93 ksi ultimate.

Maximum void 1-5/8 X 2-3/8 (sample T-1084)

Loss % at sleeve surface area	16,075%
Loss % at bar surface area	17,040%
Loss % of groove area	20,862%

(Performance exceeded 90,000 psi. in all test samples)

Horizontal Test Splice - T-14101-H

Bar 66.6 ksi yield, over 11.3 ksi ultimate.

Maximum void 3 X 2 (sample T-1085)

Loss % at sleeve surface area	24.590%
Loss % at bar surface area	26.069%
Loss % of groove area	32.104%

(Performance exceeded 90,000 psi.)

Vertical Test Splices - T-14101

Bar 66.6 ksi yield, over 11.3 ksi ultimate.

Maximum void 1 X 2 (rectangular) and 3/4" deep for full circumference.

Loss % at sleeve surface area	16.980%
Loss % at bar surface area	18.003%
Loss % of groove area	28.56%

(Performance exceeded 90,000 psi.)

CADWELD SPLICE CORRECTION FACTORS

Correction Factors based on

$$\frac{\text{Sleeve Groove Area}}{\text{Bar Area}} \quad \text{and} \quad \frac{\text{Minimum Def. Shear Area}}{\text{Bar Area}}$$

Groove Shear Area from Table IV (attached).

Bar Minimum Def. Shear Area from Table III (attached).

Bar Size	Sleeve Cat. No.	R Groove A / Bar A	Correction Factor	R Shear A / Bar A	Correction Factor
#9	C-976	3.534	.908	1.224	.802
9	T-9101	4.420	1.135	1.601	1.048
10	C-1076	3.015	.774	1.102	.722
10	T-1091	3.770	.968	1.442	.944
11	C-1176	3.306	.849	1.303	.853
11	T-11101	3.965	1.018	1.610	1.054
14	C-1461	3.338	.857	1.160	.760
14	C-1476	3.338	.857	1.283	.840
14	T-1476	3.894	1.000	1.527	1.000
14	T-14101	3.894	1.000	1.527	1.000
18	C-1861	2.707	.695	1.075	.703
18	C-1876	3.093	.794	1.245	.815
18	T-1876	3.093	.794	1.245	.815
18	T-1891	3.093	.794	1.417	.928

Use lowest (of two) correction factors.

CADWELD VOID EXTRAPOLATIONS

Assumed that 15% voids allowable on T-14101 and T-14101-H from test results. Apply lowest correction factor to this allowable percentage.

					Vertical - Full Circ. Voids		
Sleeve Cat. No.	Correction Factor	% Effective Void (%)	Eff. Bar Area (+) (in^2)	Add. Void Area (in^2)	Add. Full Circ. Void Depth (in.) (++)	Total Void Full Circ. - Depth	
						Exact (in.)*	Fraction (in.)
T-9101	1.048	15.720	7.531	1.184	.334	.544	1/2
T-1091	.944	14.160	8.479	1.201	.301	.489	1/2
T-11101	1.018	15.270	11.629	1.776	.401	.589	9/16
T-1476	1.000	15.000	16.625	2.494	.469	.657	11/16
T-14101	1.000	15.000	16.625	2.494	.469	.657	11/16
T-1876	.794	11.910	25.701	3.061	.432	.620	5/8
T-1891	.794	11.910	29.246	3.483	.491	.679	11/16
T-18101	.794	11.910	29.246	3.483	.491	.679	11/16

(+) Bar nominal perimeter times effective length from Table III (attached).

(++) Addition void area divided by par perimeter.

(*) Add void full circ. & .188.

TABLE I — SLEEVE STRESS AT TAP HOLE UNDER MAXIMUM LOAD

Bar	Sleeve Cat. No.	Sleeve O.D.	Sleeve I.D.	Sleeve Lg.	Area at tap hole	A-431 Max. Req. Load lbs.	A-431 Slv. stress at req. load psi.	A-432 Max. Load lbs.	A-432 Stress psi.	I.G. (or H.G.) Max. Load lbs.	I.G. (or H.G.) Stress psi.
#7	T-7101	1-5/8	1-1/8	5	.951	60,000	63,091	154,000	56,782	42,000	44,164
#8	T-891	1-3/4	1-1/4	5	1.049			71,100	67,778	55,300	52,717
	T-8101	1-7/8	1-1/4	5	1.373	79,000	57,538	(71,100)	(51,784)		
#9	T-9101	2-1/8	1-1/2	5	1.619	100,000	61,576	90,000	55,590	70,000	43,236
#10	T-1091	2/14	1-5/3	5	1.741			114,300	65,463	88,900	51,0[illegible]
#11	T-11101	2-1/2	1-3/4	6	2.311	156,000	67,357	140,000	60,752	109,200	47,252
#14S	T-1476	2-7/8	2-1/8	7	2.705					157,500	58,096
	T-14101	3	2-1/8	7	3.242	225,000	79,252	202,500	62,461		
#18S	T-1876	3-5/8	2-5/8	8	4.59					280,000	60,922
	T-1891	3-3/4	2-5/8	9	5.27			360,000	68,181		
	T-18101	3-7/8	2-5/8	9	5.98	400,000	66,778	(360,000)	(60,200)		

TABLE II — SHEAR AREA OF ONE REBAR DEFORMATION

Bar	Perimeter	Height	Width	Shear Area of One Deformation
#7	2.749	.044	.132	.363
8	3.142	.050	.150	.471
9	3.544	.056	.168	.595
10	3.990	.064	.192	.766
11	4.430	.071	.213	.944
14	5.320	.085	.255	1.303
18	7.090	.102	.306	2.170

TABLE III — REBAR DEFORMATION STRESS AT MAXIMUM REQUIRED LOAD

Sleeve Cat. No.	Eff. Length 1/2 - 3/8	Max. Def. Spacing	No. of Eff. Def.	Def. Shear Area	Inter. Grade		A-432		A-431	
					Max. Load	Stress on Def.	Max. Load	Stress on Def.	Max. Load	Stress on Def.
T-7101	2.125	.612	3.472	1.260	42,000	33,333	54,000	42,857	60,000	47,619
T-891	2.125	.700	3.036	1.480	55,300	38,671	71,100	49,720		
T-8101	2.125	.700	3.036	1.480					79,000	55,245
T-9101	2.125	.790	2.690	1.601	70,000	43,723	90,000	56,215	100,000	6[illegible]61
T-1091	2.125	.889	2.390	1.881	88,900	48,553	114,300	62,424		
T-11101	2.625	.987	2.660	2.511	109,200	43,488	140,400	55,913	156,000	62,127
T-1476	3.125	1.185	2.637	3.436	157,500	45,838				
T-14101	3.125	1.185	2.637	3.436			202,500	58,934	225,000	65,488
T-1876	3.625	1.58	2.294	4.978	280,000	56,247				
T-1891	4.125	1.58	2.611	5.666			360,000	63,537		
T-18101	4.125	1.58	2.611	5.666					400,000	70,597
T-11-14101	2.625	.987	2.660	2.511	109,200	43,488	140,400	55.913	156,000	62,127
T-14-18101	3.125	1.185	2.637	3.436	157,500	45,838	202,500	58,934	225,000	65,483

TABLE IV FILLER METAL STRESS AT MAXIMUM REQUIRED LOAD

Sleeve Cat. No.	Sleeve Internal Circum.	No. of Grooves	Groove Int. Shear Area	Inter. Grade		A-431		A-432	
				Max. Load	Filler Metal Stress	Max. Load	Filler Metal Stress	Max. Load	Filler Metal Stress
T-7101	3.534	5	3.315	42,000	12,670	54,000	16,290	60,000	18,100
T-891	3.927	5	3.684	55,000	15,011	71,100	19,300		
T-8101	3.927	5	3.634					79,000	21,444
T-9101	4.712	5	4.420	70,000	15,837	90,000	20,362	100,000	22,624
T-1091	5.105	5	4.788	88,900	18,567	114,300	23,872	*	
T-11101	5.498	6	6.185	109,200	17,656	140,400	22,700	156,000	25,222
T-1476	6.676	7	8.762	157,500	17,283				
T-14101	6.676	7	8.762			202,500	23,101	225,000	25,667
T-1876	8.247	8	12.371	280,000	22,634				
T-1891	8,247	8	12,371			360,000	29,100		
T-19101	8.247	8	12.371					400,000	32,334
F-11-14101	5.498	6	6.185	109,200	17,656	140,400	22,700	156,000	25,222
F-14-18101	6.676	7	8.766	157,500	17,283	202,500	23,101	225,000	25,667

* T-11101 splice kit for #11 used with extra filler material.

Appendix C

Specification No. 5610-C-30

Job No. 5610

TECHNICAL SPECIFICATION FOR SPLICING REINFORCING BAR USING THE CADWELD PROCESS

NUCLEAR POWER PLANTS
TURKEY POINT, UNITS NO. 3 & NO. 4
FLORIDA POWER AND LIGHT COMPANY

Bechtel Associates
Gaithersburg, Maryland

No.	Date	Revisions	By	Approvals	
0	12/5/66	Issued for Field Purchase	EFC	FHH	AJA
1	3/27/67	Revised Para. 1.1, 3.1, 4.1.1, 5.1.4 & 6.4	AJA	EFC	
2	4/22/68	Revised Para. 1.1, 4.1.10, 11, 12, 6.3, 4, 5 & 6	EJS	AJA	

SPECIFIC CONDITIONS

1.0 SCOPE

1.1 This Specification covers the mechanical splicing of deformed concrete reinforcing bar for full tensile loading. The average tensile strength of the Cadweld joints shall be equal to or greater than the minimum tensile strength for the particular grade of reinforcing steel as specified in the appropriate ASTM standard. The minimum tensile strength of the splices shall equal or exceed 125 percent of the minimum yield strength for each grade of reinforcing steel as specified in the appropriate ASTM Standard.

(2)

2.0 PROCESS

2.1 All splices shall be made by the Cadweld Process using clamping devices, sleeves, charges, etc., as specified by the Cadweld Instruction Sheets for "T" Series connections. "C" series materials shall not be permitted.

3.0 QUALIFICATION OF OPERATORS

3.1 Prior to the production splicing of reinforcing bars, each operator or crew, including the foreman or supervisor for that crew, shall prepare and test a joint for each of the positions to be used in production work. These splices shall be made and tested in strict accordance with this Specification using the same ASTM grade and size of bar to be spliced in the production work. To qualify, the completed splices shall meet the acceptance standards of Paragraph 6.0 for workmanship, visual quality and minimum tensile strength. A list containing the names of qualified operators and their qualification test results shall be maintained at the jobsite.

4.0 PROCEDURE SPECIFICATION

4.1 All joints shall be made in accordance with the manufacturer's instruction sheets "Rebar Instructions for Vertical Column Joints", plus the following additional requirements:

4.1.1 A manufacturer's representative, experienced in Cadweld splicing of reinforcing bar, shall be present at jobsite at the outset of the work to demonstrate the equipment and techniques used for making quality splices. He shall also be present for at least the first fifty (50) production splices to observe and verify that the equipment is being used correctly and that quality splices are being obtained.

4.1.2 The splice sleeves, exothermic powder, and graphite molds shall be stored in a clear dry area with adequate protection from the elements to prevent absorption of moisture.

4.1.3 Each splice sleeve shall be visually examined immediately prior to use to insure the absence of rust and other foreign material on the I.D. surface.

4.1.4 The graphite molds shall be preheated with an oxyacetylene or propane torch to drive off moisture at the beginning of each shift when the molds are cold or when a new mold is used.

4.1.5 Bar ends to be spliced shall be in good condition with full size, undamaged deformations. The bar ends shall be power brushed to remove all losse mill scale, rust, concrete and other foreign material. Prior to power brushing all water, grease and paint shall be removed by heating the bar ends with an oxyacetylene or propane torch.

4.1.6 A permanent line shall be marked 12" back from the end of each bar for a reference point to confirm that the bar ends are properly centered in the splice sleeve.

4.1.7 Immediately before the splice sleeve is placed into final position, the previously cleaned bar ends shall be preheated with an oxyacetylene or propane torch to insure complete absence of moisture.

4.1.8 Special attention shall be iven to maintaining the alignment of sleeve and guide tube to insure a proper fill.

4.1.9 When the temperature is below freezing or the relative humidity is above 65 percent the splice sleeve shall be externally preheated with an oxyacetylene or propane torch after all materials and equipment are in position.

(2) 4.1.10 The reinforcing bar deformations except longitudinal ribs which become engaged in the Cadweld splice shall not be ground, flame-cut or altered in any way. In no event shall be the longitudinal ribs be ground, flame-cut or altered to a lesser diameter than the bar deformations.

(2) 4.1.11 A hairpin, piece of soft twisted wire, may be inserted at the top of the horizontal splices between the rebar and the sleeve to provide an escape route for the gases generated during the casting of the filler material.

(2) 4.1.12 The packing material at the ends of the horizontal splices and at the top of the vertical splices should not be hard packed. The material should be firmly in place but loose enough to allow the escape of gases.

5.0 JOINT TESTING

5.1 All completed splices shall be visually inspected at both ends of the splice sleeve and at the tap hole in the center of the splice sleeve.

5.2 Selected production splices shall be tensile tested in accordance with the following schedule for each position, bar size and grade of bar.

1 out of first 10 splices
3 out of the next 100 splices
2 out of the next and subsequent units of 100 splices.

5.3 Test splices as noted in Section 5.2 may be made by having test bars of 3 foot length splices in sequence with the production bars. This will eliminate the need for cutting out test splices from the production work and replacing them with two (2) additional splices while still maintaining actual on site conditions.

6.0 JOINT ACCEPTANCE STANDARDS

6.1 Sound, nonporous filler metal shall be visible at both ends of the splice sleeve and at the tap hole in the center of the splice sleeve. Filler metal is usually recessed 1/4" from the end of the sleeve due to the packing material and is not considered a poor fill.

6.2 Splices which contain slag or porous metal in the riser, tap hole or at the ends of the sleeves (generally proosity) shall be rejected. A single shrinkage bubble present below the riser is not detrimental and should be distinguished from general porosity as described above.

(2) 6.3 There shall be evidence of filler material between the sleeve and bar for the full 360 degrees.

(2) 6.4 The splice sleeves need not be exactly concentric or axially aligned with the bars. However, there shall be a minimum of 1/16 of an inch between the splice sleeve and deformations of the reinforcing bar. This condition of maximum acceptable eccentricity or concentricity may be measured using a stiff 1/16" diameter wire.

(2) 6.5 The Cadweld splices, both horizontal and vertical, may contain void at either or both ends of the Cadweld splice sleeve. At the end of the Cadweld splice sleeves the acceptable size void for an 18S splice shall not exceed three (3) square inches per end of splice sleeve. The area of the void shall be assumed to be the circumferential length as measured at the inside face of the sleeve times the maximum depth of wire probe minus 3/16".